N-63 4-3

HEL - 2 - 5

SAND TRANSPORT BY WIND
STUDIES WITH SAND C
(0.145 MM DIAMETER)

by

ABDEL - LATIF KADIB

HYDRAULIC ENGINEERING LABORATORY
WAVE RESEARCH PROJECTS

UNIVERSITY OF CALIFORNIA
BERKELEY

University of California
Hydraulic Engineering Laboratory
Wave Research Projects

Submitted under Contract DA-49-055-CIV-ENG-63-4 with the
Beach Erosion Board, Corps of Engineers, U. S. Army

Institute of Engineering Research
Technical Report
HEL - 2 - 5

SAND TRANSPORT BY WIND
STUDIES WITH SAND C (0.145 MM DIAMETER)

by

Abdel-Latif Kadib

Berkeley, California
June, 1963

SAND TRANSPORT BY WIND

STUDIES WITH SAND C (0.145 MM DIAMETER)

by

Abdel-Latif Kadib

This study on the variation in the rate of sand transport with the wind velocity was made with a sand having a mean diameter of 0.145 mm and grain size distribution as shown in Fig. 1.

The experimental procedure essentially was the same as that used by Belly (1) in tests on Sand A (D = 0.44 mm), and Sand B (D = 0.30 mm). The only difference in the procedure was that to obtain wind velocities as low as 10 ft/sec, it was essential to open some of the top covers of the wind tunnel. Vertical wind profiles were measured for different combinations of cover openings. The results of these tests are shown in Fig. 2.

Sand was fed into the upper end of the tunnel in all runs.

The shear velocity U_* was calculated using Zingg's formula:

$$U = 6.13\, U_* \,\mathrm{Log}\, \frac{Z}{Z'} + U'$$

The experimental threshold velocity (with sand feed) was 22.0 Cm/sec and that calculated by the Bagnold formula was 17.6 Cm/sec. The difference between the observed and the calculated values of the threshold velocity is due to the use of a constant value for A in the Bagnold formula:

$$U_{*_t} = A \quad \frac{\sigma - \rho}{\rho}\, gd$$

(1) Belly, Pierre-Yves, Sand Movement by Wind, Univ. of Calif. Inst. of Engin. Res., Series 77, Issue 7, July 1962.

Bagnold showed that the value of A, for a grain size of 0.20 mm or less, is not a constant. The coordinates of the focal point of the vertical velocity distribution curves were obtained from Fig. 3.

$$Z' = 0.0125 \text{ ft}$$

$$U'' = 6.4 \text{ ft/sec}$$

These values did not agree with that obtained from the Zingg equation, i.e.

$$Z' = 0.0048 \text{ ft}$$

$$U' = 4.25 \text{ ft/sec}$$

Table 1 gives the experimental data obtained from these tests. These data are plotted in Fig. 4.

Figure 5 shows the experimental values of sand transport compared with values calculated by the Bagnold and Kawamura formulas. In this comparison, a value of C = 1.5 was used in the Bagnold formula. This is the lower value for the value of C recommended by Bagnold and applies to a uniform grain size. For the Kawamura formula a value of K = 1.0 had to be selected in order that the calculated curve would pass near the experiential points.

<u>Comparison with O'Brien and Rindlaub formula</u>

O'Brien and Rindlaub (2) proposed the following formula from data derived from the field tests:

$$G = 0.036\ U_5^3 \quad (\text{for } U_5 > 20 \text{ ft/sec})$$

where G is the rate of movement of dry sand in pounds per day passing

(2) O'Brien, M. P. and Rindlaub, B. D., The transportation of sand by wind, Civil Engin., May 1936, pp 325-326

an imaginary line 1 foot in length drawn perpendicular to the wind, and U_5 is the wind velocity 5 ft. above the sand surface in ft/sec. During the field tests the sand caught in the sand trap had a median diameter between 0.17 mm and 22 mm.

In order to compare the test results with the O'Brien and Rindlaub formula, the velocities 5 ft. above the sand bed in the present tests were calculated using Zingg's formula; i.e.,

$$U = 6.13\, U_* \operatorname{Log} \frac{Z}{Z} + U'$$

This calculation was made for Sand A (D = 0.44 mm), Sand B (D = 0.30 mm) and Sand C (D = 0.145 mm). Tables 2, 3 and 4 show the calculations for Sands A, B, and C, respectively. Figure 6 shows the plots of the experimental data compared with the O'Brien and Rindlaub formula.

The experimental values for the sand transport are compared with the O'Brien and Rindlaub formula as follows:

Sand A (D = 0.44 mm). The data follow a straight line the slope of which is about 6.00 instead of 3.00 as found by O'Brien and Rindlaub (Fig. 6a). Also the value of the constant (0.036) in their formula was found to be about 0.76×10^{-6} for sand A. This limits the use of their equation to sand with a grain diameter similar to what they tested (D = 0.195 mm). For Sand A (D = 0.44 mm) the best description is

$$\underline{G = 0.76 \times 10^{-6}\, U_5^{6.00}}$$

Sand B (D = 0.3 mm). Experimental data follow a straight line parallel to the O'Brien and Rindlaub curve but shifted to the left (Fig. 6b). The value of the constant for Sand B was found to be 0.065. For Sand B(D=0.3mm) the best description is

$$G = 0.065 \times U_5^{3.00}$$

Sand C (D = 0.145 mm). Figure 6c shows a scatter of the experimental data around the O'Brien and Rindlaub curve. The scatter does not seem to be significant. This sand was the only one which agrees with the O'Brien and Rindlaub formula. This agreement probably is because Sand C(D=0.145 mm) has approximately the same order of magnitude of grain diameter as found in the O'Brien and Rindlaub tests (D = 0.195 mm).

CONCLUSION

1. The value of threshold velocity is best determined by experiment when the grain size is less than 0.20 mm.
2. The value of C in Bagnold's formula has less scatter than the coefficient K in Kawamura's formula.
3. The use of the O'Brien and Rindlaub formula must be limited to sand having the same grain diameter of that tested.

Table 1

Wind velocity at Z = 1.0 ft. in ft/sec	Shear velocity U_* in cm/sec	Rate of transport in gr/cm-sec
14.70	24.40	0.00167
16.00	27.80	0.0277
18.20	33.60	0.0590
19.40	36.80	0.0880
21.00	41.00	0.114
26.60	55.50	0.278
28.00	59.50	0.189
29.20	62.60	0.270
30.00	64.50	0.365
33.20	73.00	0.475
34.20	76.00	0.530
35.40	79.00	0.645
36.00	80.50	0.736
37.50	84.50	0.950
38.90	88.00	0.945

Table 2

Calculations for U_5 using Zingg's Formula
Sand A (D = 0.44 mm)

$U' = 13$ ft/sec
$Z' = 0.0135$
$U_5 = U_* \cdot 6.13 \text{ Log } \frac{5}{0.0135} + 13.0$
$U_5 = 15.7 U_* + 13.00$

U_*	$15.7 U_*$	U_5 ft/sec	q lb/ft-day
1.48	23.2	36.2	1820.0
1.48	23.2	36.2	1690.0
1.52	23.8	36.8	2220.0
1.65	25.8	38.8	2920.0
1.68	26.40	39.4	3160.0
1.71	27.00	40.0	3360.0
1.78	28.00	41.0	4050.0
1.81	28.40	41.4	4540.0
1.91	30.00	43.0	5260.0
2.1	33.00	46.0	5850.0
0.99	15.50	28.50	69.50
1.15	18.10	31.10	610.0
1.25	19.60	32.60	1055.0
1.28	20.20	33.20	1280.0
1.35	21.20	34.20	1350.0
1.52	23.80	36.80	1625.0
1.65	25.80	38.80	2930.0

Table 3

Calculations for $U_{5\ ft}$ using Zingg's Formula

Sand B (D = 0.30 mm)

$U' = 9$ ft/sec
$Z' = 0.010$

$$U_5 = U_* \, 6.13 \, \mathrm{Log}_{10} \frac{5}{0.010} + 9.00$$

$$= 16.5 \, U_* + 9$$

U_* ft/sec	$16.5\ U_*$ ft/sec	U_5 ft/sec	q lb/ ft-day
0.545	8.70	17.70	0
0.825	13.60	22.60	665.0
0.99	16.30	25.30	930.0
1.085	17.80	26.80	1270.0
1.180	19.50	28.50	1680.0
1.315	21.70	30.70	1680.0
1.35	22.30	31.30	2140.0
1.42	23.40	32.40	2320.0
1.58	26.00	35.00	2960.0
1.90	31.40	40.40	4400.0
2.10	34.80	43.80	5600.00

Table 4

Calculation of $U_{5\ ft}$ using the Logarithmic Formula

Sand C (D = 0.145 mm)

Using the Modified Wind Velocity Distribution

$$u = 6.13\, U_* \, \mathrm{Log}_{10} \frac{Z}{Z_o} + u'$$

$$u_5 = 6.13 U_* \, \mathrm{Log} \frac{5}{.0125} + 5.40$$

$$= 6.13\, U_* \, \mathrm{Log}\, 400 + 5.4$$

$$= 6.13 \times 2 - \quad U_* + 5.4$$

$$u_5 = 16.0\, U_* + 5.4$$

Run	U_* ft/sec	$16u_*$ ft/sec	U_5 ft/sec	Q lb	T min.	q lb/ft-day
3	.915	14.6	20.00	9.15	41.0	160.5
4	.804	12.8	17.90	0.55	41.0	9.65
5	1.95	31.2	36.60	28.9	20	1038.0
6	2.05	33.0	38.40	66.40	30	1590.0
7	2.40	38.4	43.80	76.9	20.	2760.0
8	2.98	46.3	51.70	68.6	9	5500.0
9	2.50	40.0	45.40	85.2	20	3070.0
10	2.60	41.6	47.00	62.5	12	3740.0
11	2.12	34.0	39.40	29.5	10	2150.0
12	2.78	44.50	49.90	46.0	6	5500.0
13	2.65	42.50	47.90	29.6	5	4260.0
14	1.10	17.40	22.90	5.8	12	348.0
15	1.21	19.40	24.90	5.0	7	514.0
16	1.35	21.60	27.00	5.5	6	660.0
17	1.83	29.30	34.70	13.5	6	1620.0

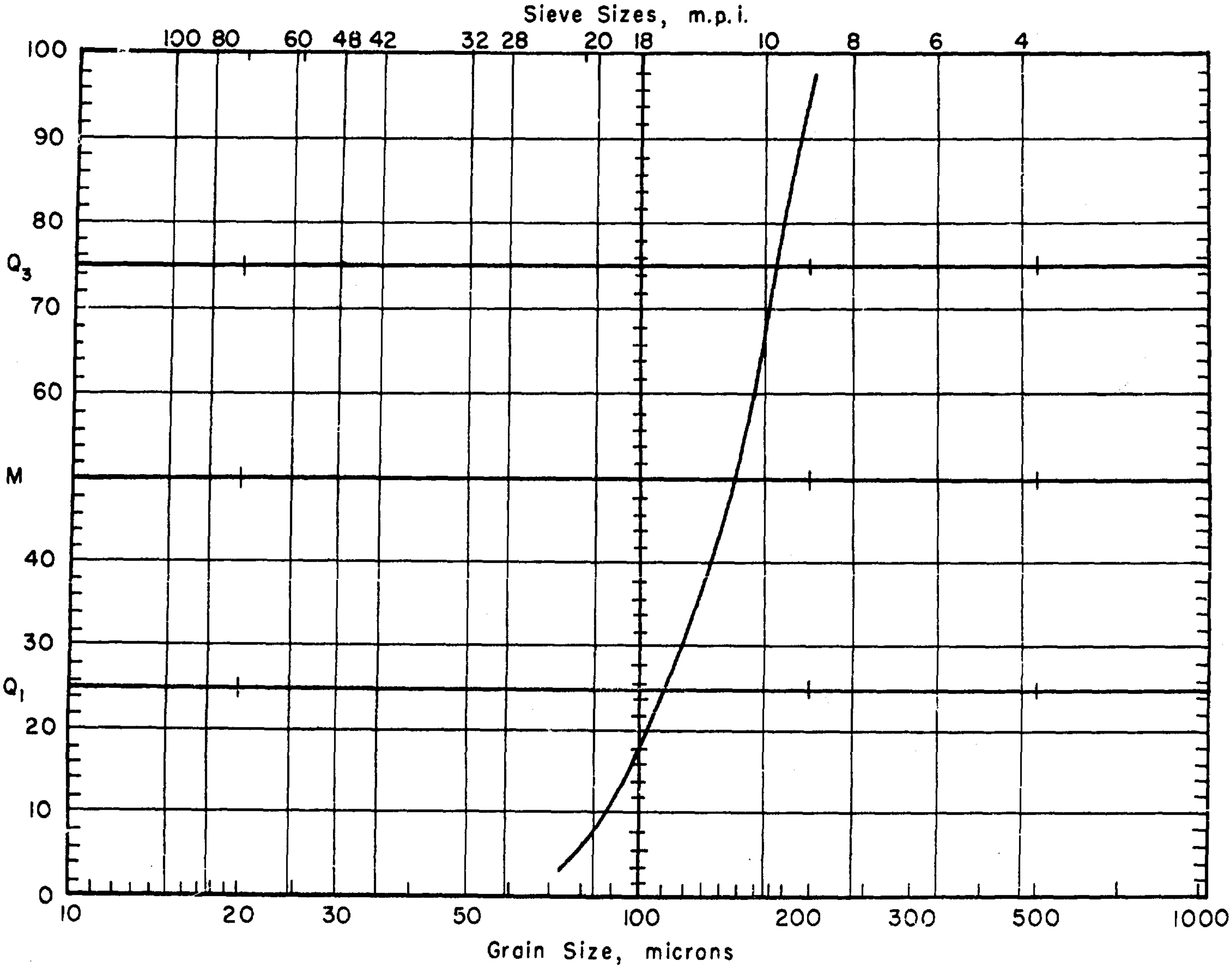

FIGURE 1. MECHANICAL ANALYSIS OF SAND

HYD 9177-A

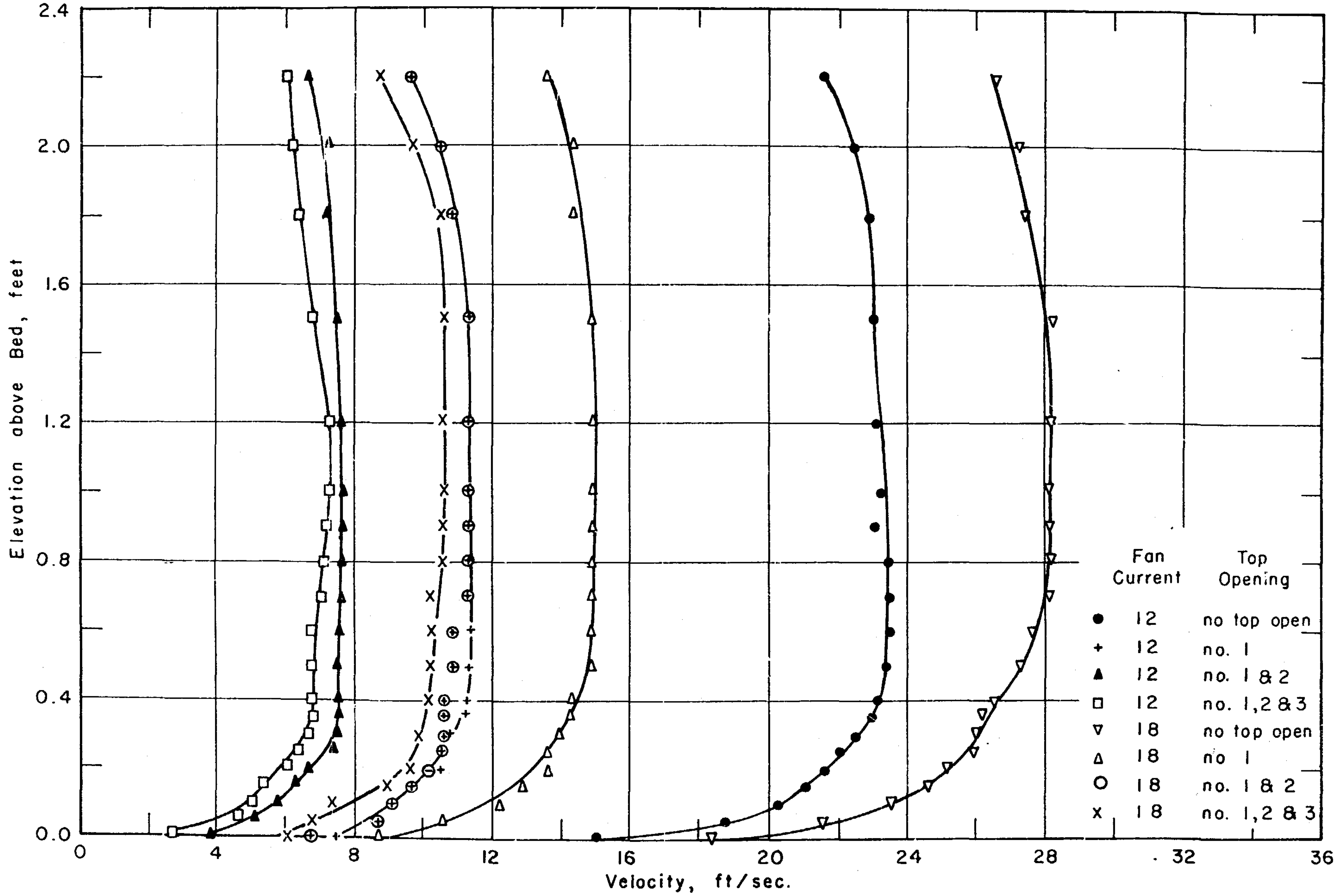

FIGURE 2. EFFECT OF TOP OPENINGS ON VERTICAL WIND PROFILE

HYD 9178-A

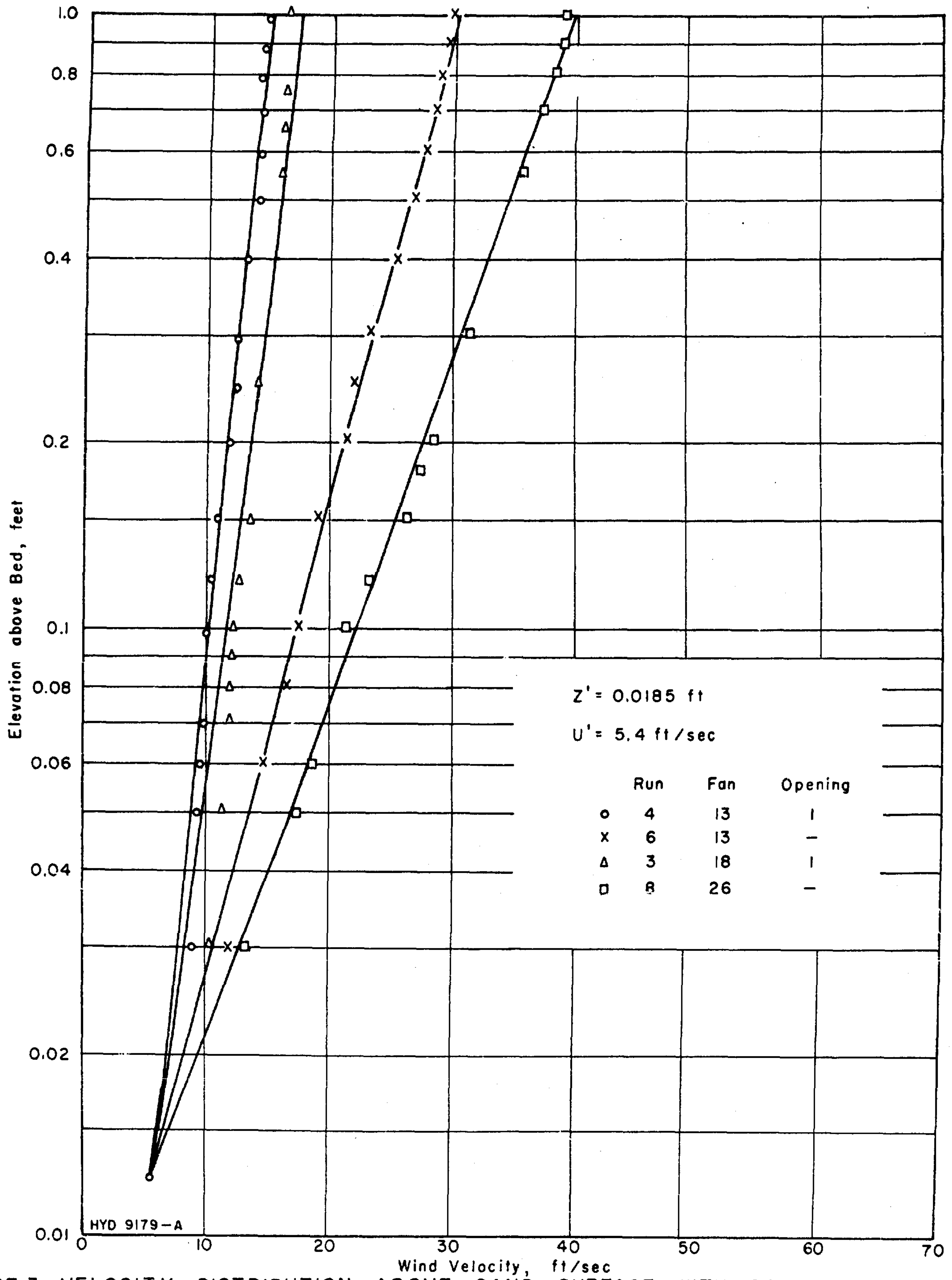

FIGURE 3. VELOCITY DISTRIBUTION ABOVE SAND SURFACE WITH SAND MOVEMENT

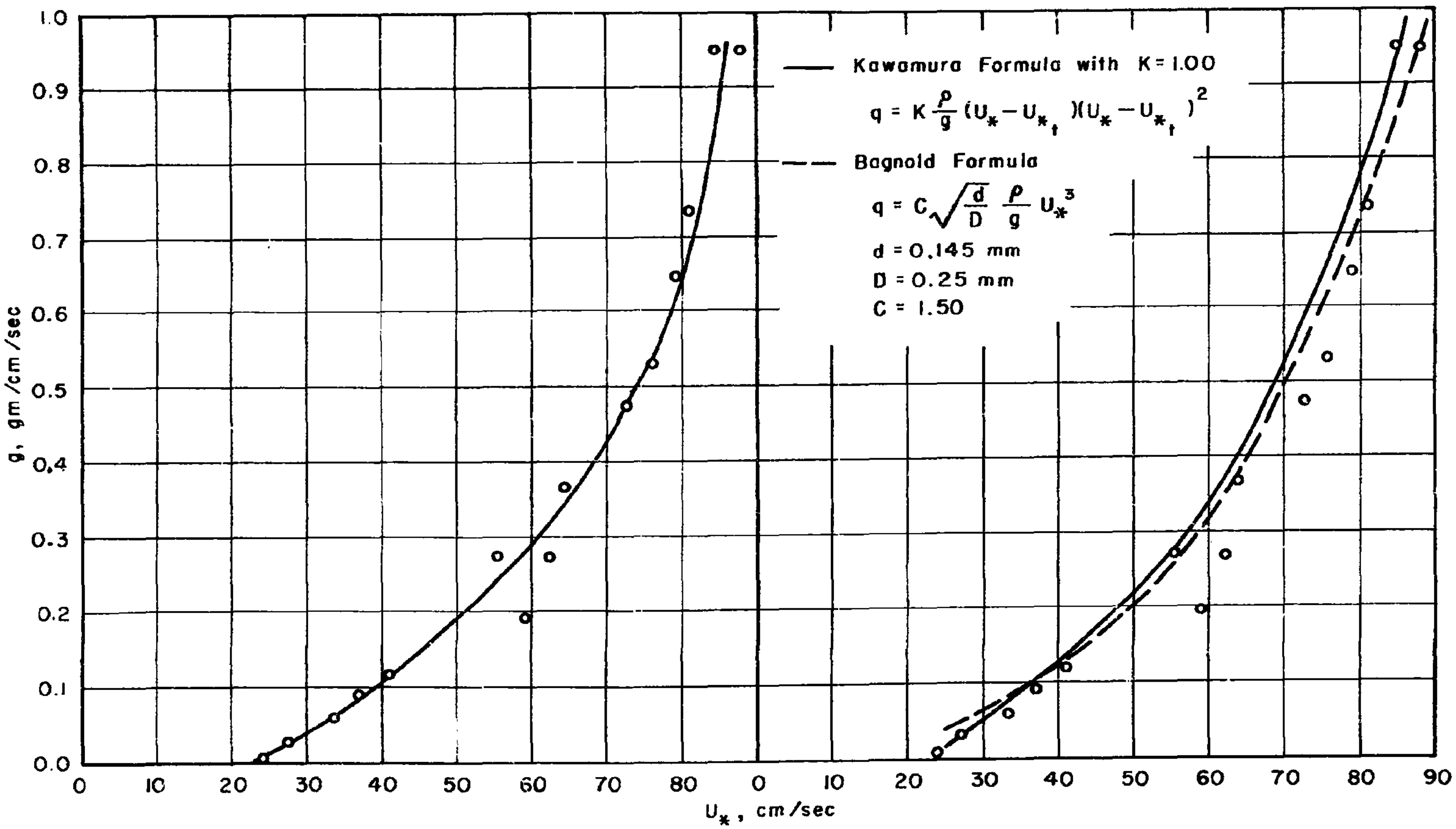

FIGURE 4. RATE OF SAND TRANSPORT (D = 0.145 mm)

FIGURE 5. COMPARISON BETWEEN EXPERIMENTAL RESULTS WITH BAGNOLD AND KAWAMURA FORMULA USING U_{*_t} FROM TEST ≐ 22 FT/SEC

HYD 9180-A

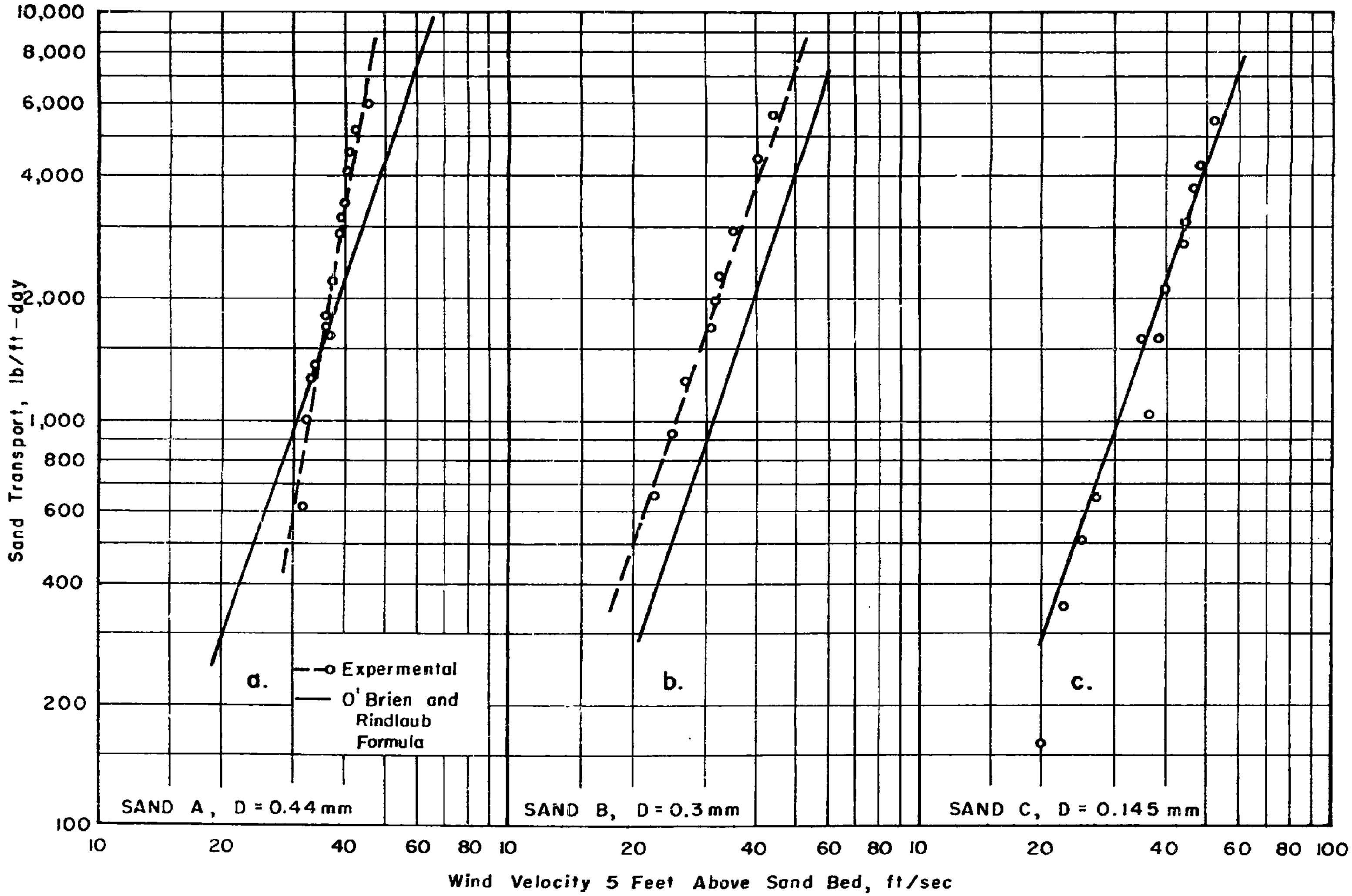

FIGURE 6. COMPARISON BETWEEN EXPERIMENTAL DATA AND THE O'BRIEN AND RINDLAULB FORMULA

HYD 9181-A